

SPARC Dynamics and Variability Project and its Connection to C20C

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Outline

- * Introduction

Why care about the stratosphere?

- * Dynamics and Variability Project

Research Questions & Approach

- * Connections to C20C

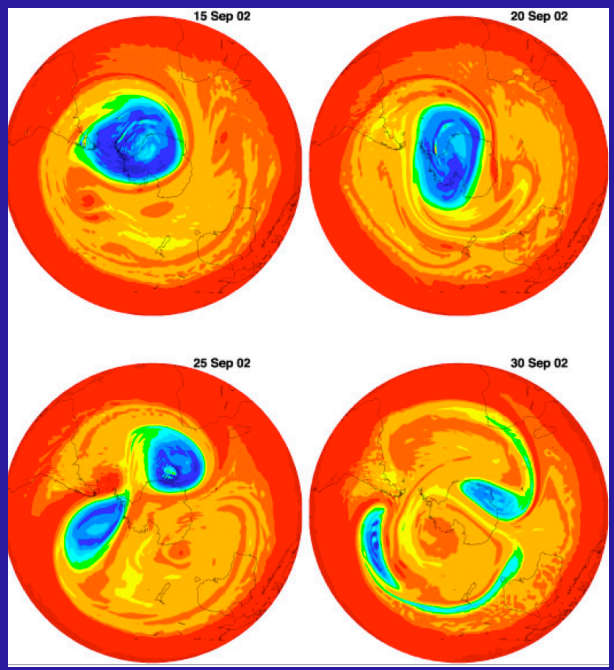
Comparing high-top and low-top C20C Runs

- * Conclusion

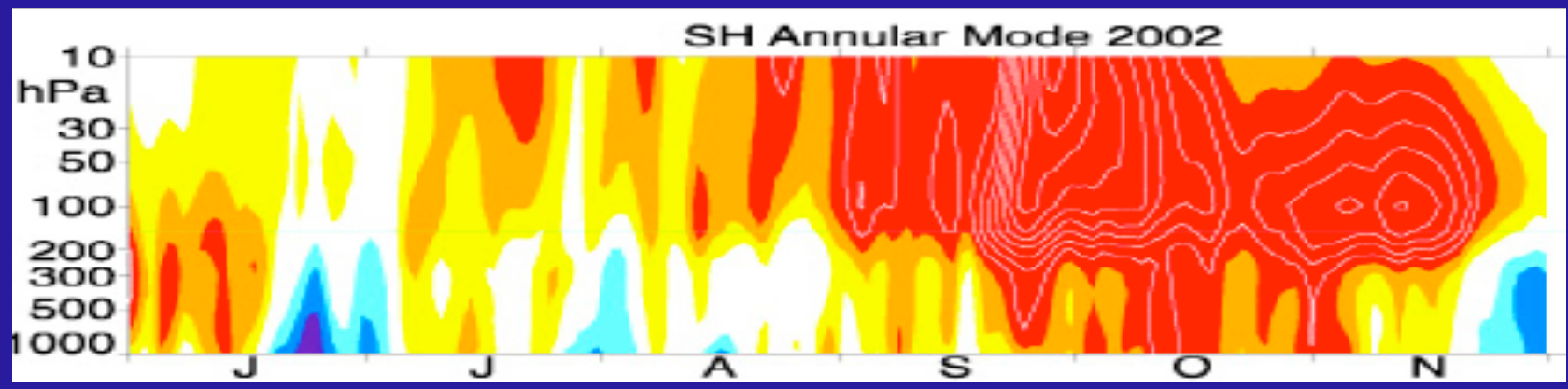
Plans, Pitfalls, Grounds for Optimism

Southern Hemisphere Sudden Warming of 2002

PV Signature

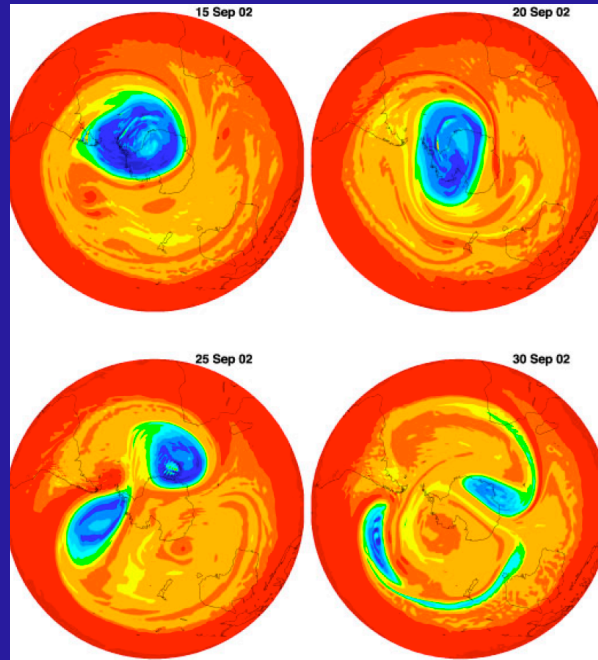


SAM Signature



Southern Hemisphere Sudden Warming of 2002

PV Signature



The SH SSW...

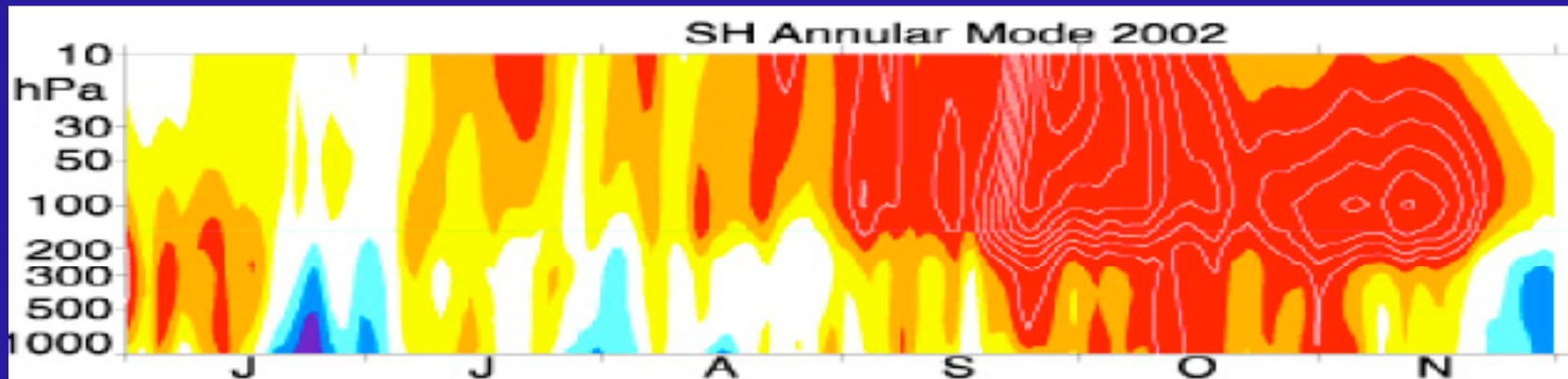
... was a surprise

... was unprecedented

... remains poorly explained

... had tropospheric signatures

SAM Signature



Baldwin et al. 2003

Introduction

- * We know that the troposphere affects the stratosphere through upward propagating atmospheric waves.
- * But several lines of research suggest that the stratosphere can in turn influence the tropospheric circulation.
- * This influence acts on intraseasonal through climate time scales.

(Key papers by Boville, Kuroda & Kodera, Baldwin & Dunkerton, Shindell et al., Thompson & Solomon, Gillett and Thompson)

Introduction

- * Research into the dynamical influence of the stratosphere on the troposphere is a key part of the WCRP SPARC program.
- * The goal of the SPARC Dynamics and Variability Project is to approach the issue of stratospheric influence in a systematic general circulation model (GCM) intercomparison framework.
- * We wish to determine how GCMs' stratospheric representation affects tropospheric climate, variability, and climate response.

Project Questions

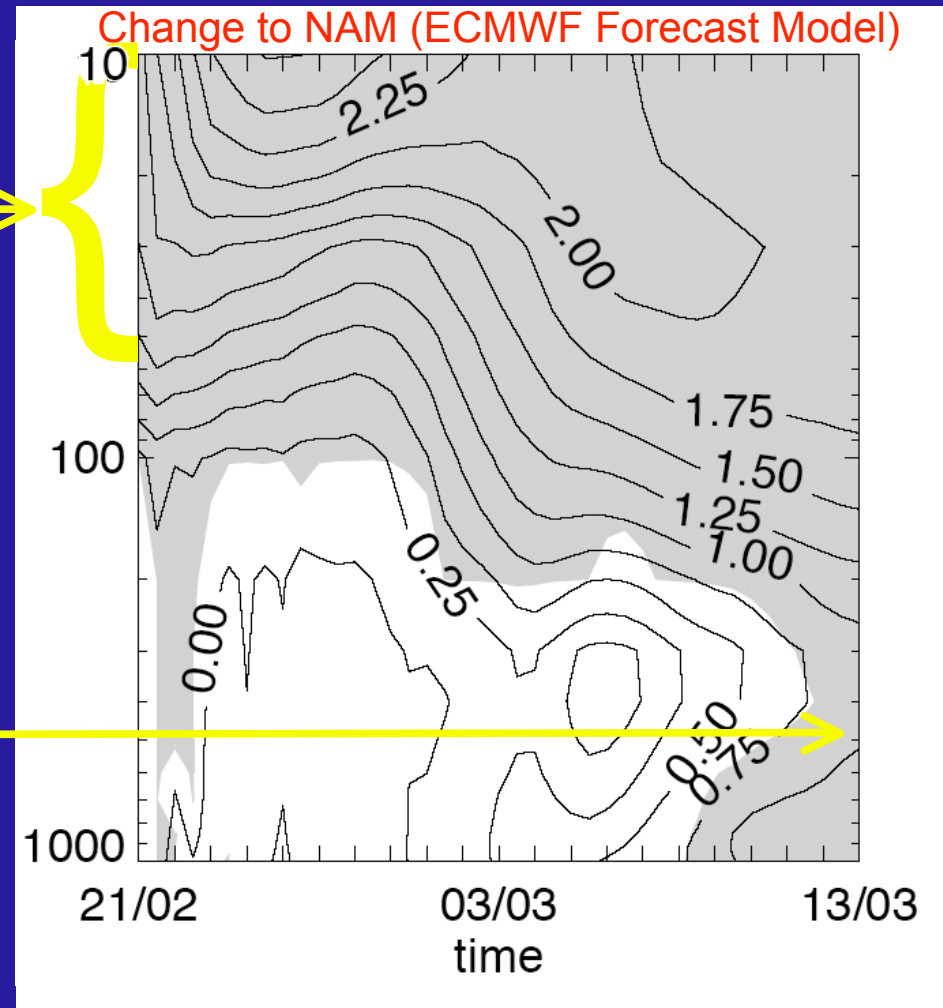
1. Stratospheric Representation in Climate Models

- * To what extent, and in what way, does a poor representation of the stratosphere degrade the simulation of tropospheric circulation in GCMs?
- * Climate modelers need to apply fixes near the lids of tropospheric GCMs, such as roof/Rayleigh drag. How do these affect atmospheric GCM simulations?
- * Stratospheric models are strongly controlled by GWD parameterizations. How does the setup of these parameterizations affect the troposphere?
- * How does resolving the stratospheric circulation affect coupled ocean-atmosphere simulations?

2. Impact of the Stratosphere on Climate Variability

Charlton et al. (2004) impose climatological stratospheric conditions near the time of a sudden warming.

The troposphere shows a significant response at later times.



2. Impact of the Stratosphere on Climate Variability

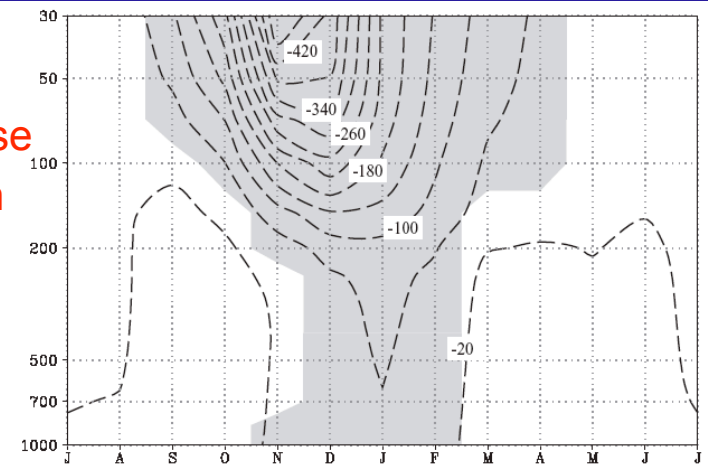
- * How does stratospheric variability on all timescales impact the troposphere?
- * Does the stratosphere influence the tropospheric tropical and extratropical response to ENSO?
- * Can we better understand the dynamics of stratosphere-troposphere coupling in the extratropics?
- * What are the implications of stratosphere-troposphere coupling for long-range weather forecasts and seasonal prediction?

3. Impact of the Stratosphere on Climate Change

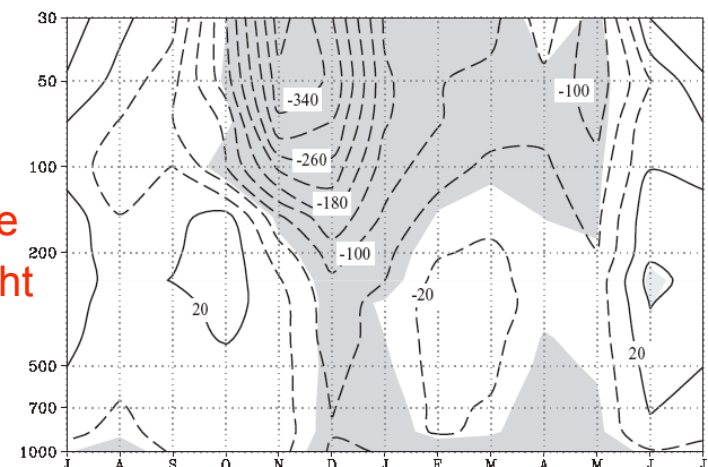
Gillett and Thompson impose observed ozone depletion in a comprehensive GCM.

The tropospheric response accounts for the observed DJF trends.

Simulated response to ozone depletion (UKMO model)



Trend in Antarctic Polar-Cap Average Geopotential Height



3. Impact of the Stratosphere on Climate Change

- * How will stratospheric climate change affect the tropospheric circulation and the coupled ocean-atmosphere system?
- * How do we explain dynamically the downward influence of Southern-Hemisphere ozone depletion on the tropospheric circulation?
- * Are stratospheric dynamical processes required to explain tropospheric circulation trends over the 20th century?

Modelling Approach

- * We focus on new runs of stratosphere-resolving AGCMs with prescribed chemistry . . .
 . . . as opposed to stratosphere-resolving coupled chemistry models (CCMs) with interactive chemistry.
- * Prescribing chemistry simplifies interpretation and involves less computational cost.
- * (But of course we will not exclude models just because they run with interactive chemistry.)

Why Should We Care?

- * Some practical questions

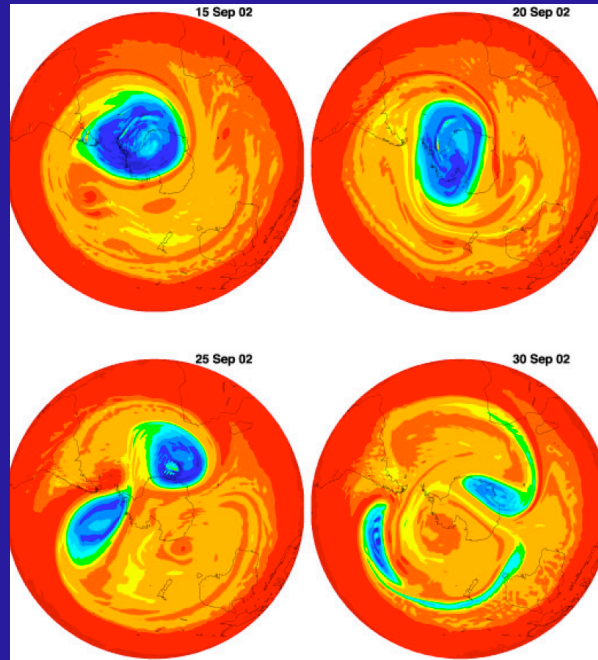
How well do we need to resolve the stratosphere for the purpose of accurate climate assessment?

Does the next generation of Earth Systems Models require a “good” stratosphere? And how good?

- * We hope that this project will guide the requirements for the development of AGCMs with appropriate stratospheric representation.

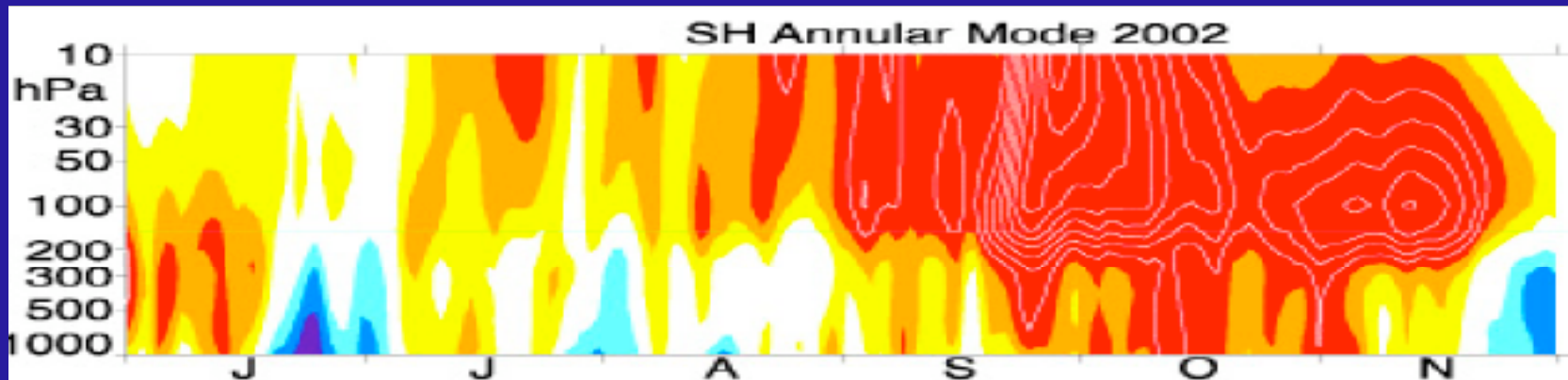
Southern Hemisphere Sudden Warming of 2002

PV Signature



What kind of AGCM is required to capture the statistics of sudden warmings and other aspects of stratospheric variability?

SAM Signature



Baldwin et al. 2003

AGCM Requirements

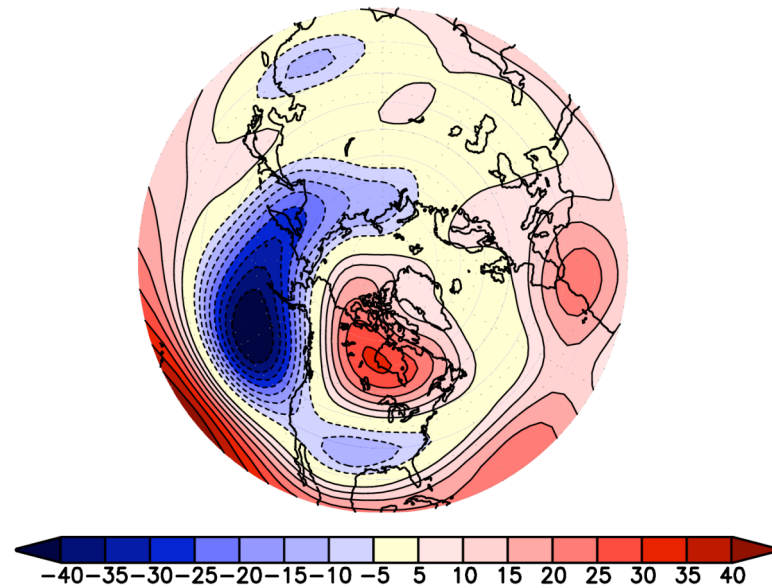
- * The models should nominally resolve
 - Baroclinic eddies in the troposphere,
 - Rossby wave breaking in the stratosphere,
 - Vertical and horizontal structure of planetary Rossby waves.
- * This suggests a minimum T42 resolution with 35-40+ vertical levels and a top at 1 mb or higher.
- * We will not insist on a QBO simulation.
- * We will also formulate data output requirements and hope to piggyback as much as possible with existing projects (CCMVal, AR4, C20C)

Proposed Runs

- * We want to look at stratospheric impacts in a systematic way over a 5-7 year period.
- * Compare tropospheric “low-top” and stratospheric “high-top” integrations with:
 - Prescribed SST
 - Slab mixed-layer ocean
 - Coupled ocean atmosphere
- * Since various centres are doing this anyway, we have an opportunity to compare and share results.

Points of Contact with CLIVAR C20C

Z500 Regression on NINO3



- * How does stratospheric representation affect tropospheric variability and climate responses?

C20C Ensemble Integrations

- * Various groups have run C20C ensembles (historical SSTs & forcing).
- * We want to compare existing high-top and low-top versions of these integrations.
- * We also want to encourage a wider set of groups to explore stratosphere-resolving models.

Analysis of C20C Integrations

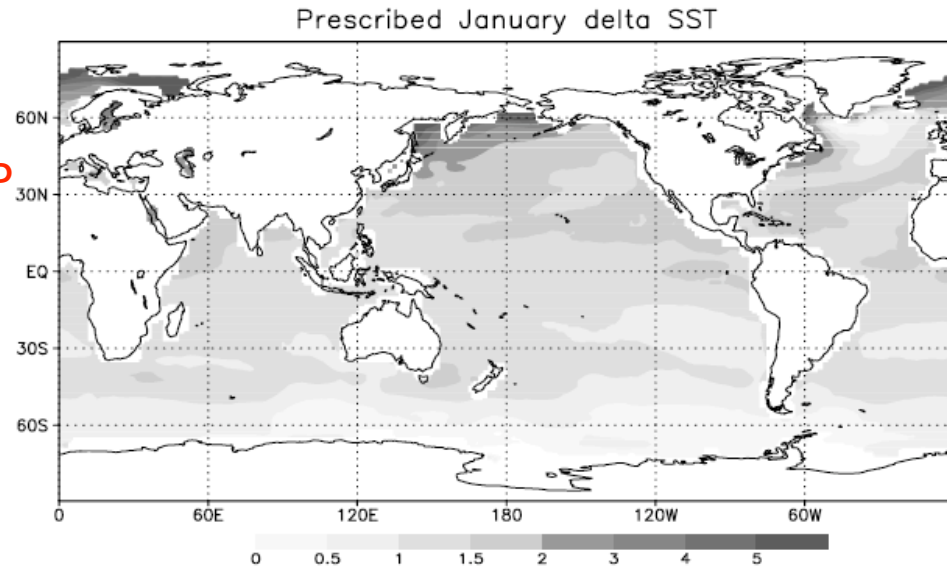
- * From a SPARC viewpoint, for the C20C integrations, how does stratospheric representation impact . . .
 1. . . . simulated climate?
Zonal mean winds, surface wind stresses, stationary waves, storm tracks, EP fluxes.
 2. . . . tropospheric variability?
ENSO teleconnections, annular mode signals.
 3. . . . climate trends?
Annular mode responses, stationary wave responses.

Additional Elements of the SPARC Project

Additional Integrations

- * Hi-top and low-top versions of “global warming” snapshot experiments. See *Cash et al. 2005*, *Sigmond et al. (under review)*.
- * Here we force high-top and low-top AGCMs with a consensus estimate of ocean surface warming.

Δ SST from CMIP ensemble, time of 2xCO₂

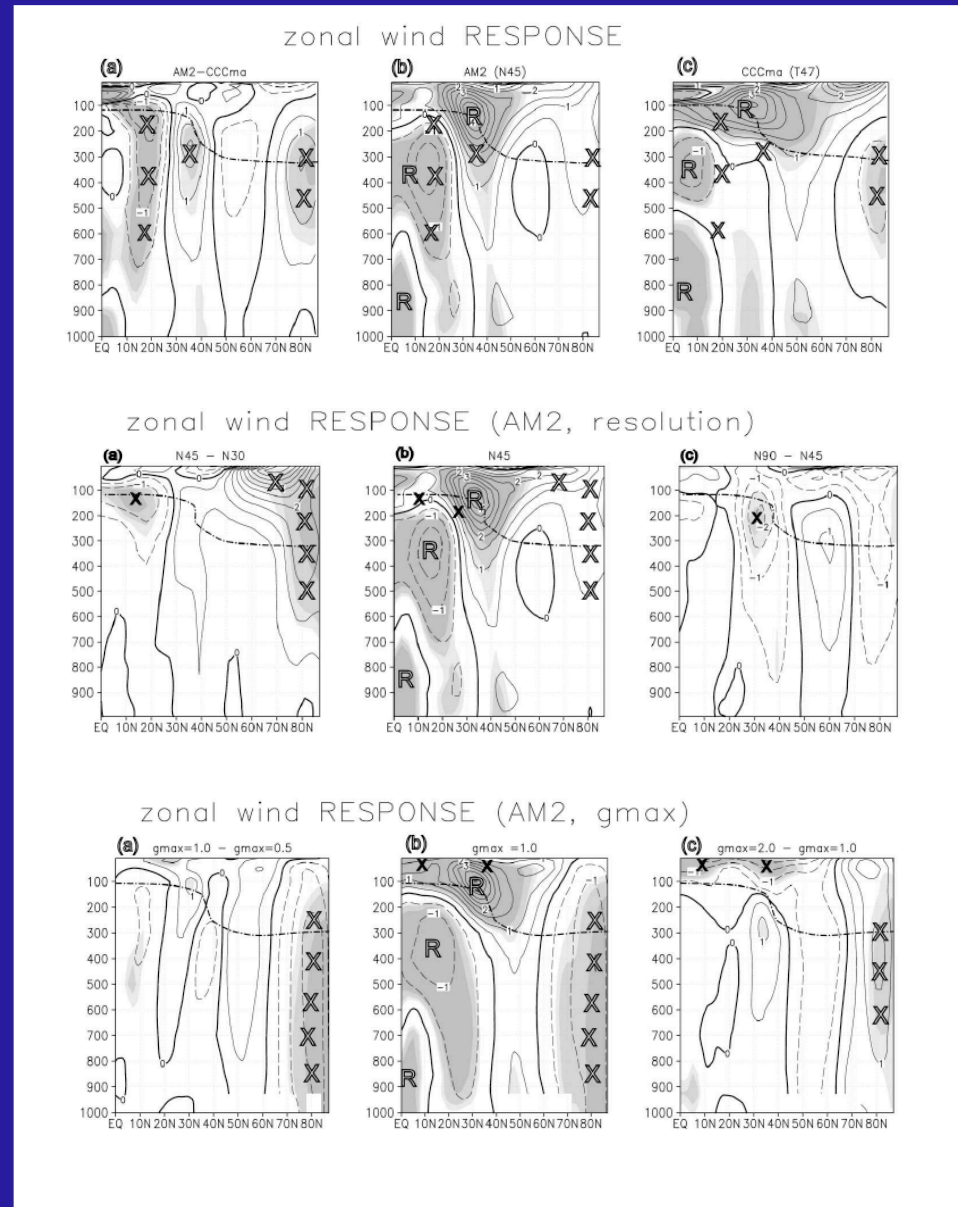


Hierarchy of Comparisons (Sigmond et al. JGR, under review)

- * Level I: Comparing independent models

- * Level II: Varying several parameters (changing resolution)

- * Level III: Varying a single parameter (oro GWD strength)



Coupling to a Mixed-Layer Ocean

- * We compare high-top and low-top AGCMs coupled to a slab MLO and ask ...

How is the “reservoir” of stratospheric memory affected by the oceanic thermal inertia?

How does coupling to an ocean affect strat-trop coupling, predictability, persistence?

Coupling to a Dynamical Ocean Model

- * Some centres are now coupling stratospheric CCMs to dynamical ocean models.
- * We are suggesting that centres also do runs with prescribed chemistry to better understand stratospheric impacts.
- * E.g. at the CCCma, two versions of the coupled AOGCM with stratospheric resolution are being put together:
 - Coarser resolution, interactive chem., for WMO ozone assessment purposes.
 - Finer resolution, prescribed chem., for this project, e.g. examining strat impacts on the response to greenhouse warming.

Organization

- * We started putting together these ideas in October 2006 at the SPARC SSG meeting.
- * We decided that stratospheric scientists need to “put their money where their mouth is” with regards to stratospheric influence. This requires looking at the system from the ocean up.
- * The current project membership draws from several modeling centres and Universities.
- * We aim to coordinate and to work within the strategic plans of the modeling centres...but to persuade them to take the stratospheric issue seriously.

Links to Other Projects

- * SPARC's CCMVal Project provides input to the WMO Ozone assessment.
 - Our circulation focus is complementary to CCMVal; we plan to use CCMVal archive runs.
- * MPI and the UKMO are already active in the area of stratospheric impacts on circulation.
- * In Canada, there is funding for a University/CCCma collaboration in this area.
- * In the U.S., Perlwitz and Sassi have a related proposal submitted to NSF IPY.

Activities

- * Telecon in December 2006 and project description from PJK for wide distribution.
- * SPARC Newsletter article this spring.
- * Upcoming meetings. Dedicated session at 2008 SPARC Congress.
- * The Victoria, Toronto, and Boulder groups are in close contact.

Potential Pitfalls

- * Lack of focus. C20C connection should help this.
- * Details of model set up and data sharing. I'm open to ideas.
- * Difficulty of cleanly comparing low-top and high-top models. We need to look for robust effects.
- * Strong control of simulations by GWD schemes.

Reasons for Optimism

- * Improving the stratospheric simulation in climate models is a relatively tractable problem (compared to e.g. parameterizing convection).
- * *Observations:* The large-scale processes that dominate extratropical strat-trop interactions are well characterized in the reanalysis products.
- * *Numerics:* These large-scale processes can be expected to converge as vertical resolution is increased. Control by GWD will remain an issue.
- * *Resources:* A dynamical MA component requires about 2 times the CPU resources of the atmospheric component, and about 1.5 times for a coupled ocean-atmosphere simulation.